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(71) Applicant: EASTMAN KODAK COMPANY
Rochester, New York 14650-2201 (US)

(72) Inventors:
- Young, Richard Dean
Rochester, New York 14650-2201 (US)
- Reed, Robert John
Rochester, New York 14650-2201 (US)
- Crosdale, Fitzroy Hugh
Rochester, New York 14650-2201 (US)

(74) Representative: Buff, Michel et al
Kodak-Pathé
Département des Brevets et Licences CRT
Centre de Recherches et de Technologie
Zone Industrielle
71102 Chalon sur Saône Cédex (FR)

(54) Apparatus and method for counting sheets

(57) An apparatus and method for counting sheets of thin media is provided by illuminating with an LED array 24 the edge 5 of a plurality of sheets 8. A linear CCD array camera 20 receives the reflected light from the sheets 8, and generates a signal waveform responsive to variations in the reflected light corresponding to the sheets. A digitizer then converts the signal into a digital signal waveform for storage in a video buffer 36. The stored signal waveform is thereafter processed along one dimension of said edge using a digital signal processor 34 for locating the positions of the sheets in the waveform, and then counting the sheets. Preferably, the linear CCD array camera 20 provides a one-dimensional image of the edge 5, however a two-dimensional CCD array may be used with additional signal processing to translate its two-dimensional signal into a one-dimensional signal. The apparatus further can locate in the signal waveform rigid portions called stiffener boards 9 which border the plurality of sheets 8 or lie at intervals between the sheets. The processing in this apparatus is automatically adaptive to sheets of different media type, edge conditions, and the presence or absence of stiffener boards 9. The apparatus can be used for counting sheets comprising a pack 10, or the rotational convolutions 74 of media on a roll 70.

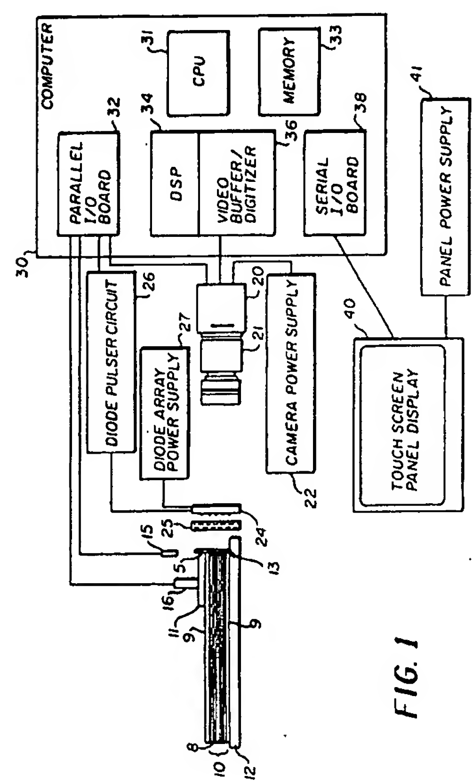

FIG. 1

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Description

FIELD OF THE INVENTION

The present invention relates generally to an apparatus and method for counting the number of sheets in a pack of sheets. In particular, it relates to an apparatus and method for counting the number of such sheets in a pack with adaptive processing to count types of thin media with different sheet thickness, coatings, material, edge cut quality, and the like. The invention is especially suitable for use in counting film of the type on which photographic negatives or positives are made, and for counting paper of the type on which photographic prints are made.

BACKGROUND OF THE INVENTION

Current manufacturing processes in the photo-finishing, film-making or paper-making industry often produce, as an intermediate or final product, packs of thin sheet media. Sheet making machines can have extremely fast throughput rates and prohibitive space constraints for sensing individual sheets making it difficult to count individual sheets prior to the formation of the pack. Therefore, it is often desired for quality assurance reasons to count at extremely high rates of speed the total number of sheets once in their pack format prior to pack handling operations such as packaging. For thin sheet media of a photographic type, such as film sheets coated with photo-sensitive material, it is desired that there be no contact between the counting device and the media surface to prevent damage to any photo-sensitive coatings.

It is also desirable to reduce damage to the packs during operator handling. To this end, cardstock or an encompassing folder of greater rigidity and thickness than the media is often used to provide stiffening support and protection during handling. Therefore, a pack may be defined as a plurality of stacked sheets bounded on the top and bottom by more rigid material, sometimes called stiffener cards or boards. These stiffener boards may also be located throughout the pack to serve as separators delineating smaller batches of the sheets. Any counting device must accommodate these stiffener boards and be able to differentiate them from media sheets while still accurately counting every sheet, including those directly adjacent to the stiffener boards.

The conventional ways of counting sheets in a pack format include manual counting, or using a measurement analysis. Manual counting requires an operator to manually hand count or visually discern and count sheets. This is both tedious to the operator and inaccurate due to human error. Measurement analysis involves measuring a pack's total attribute, such as height or weight, and dividing by the attribute of a single sheet. This generates count inaccuracies due to accumulated errors in the total measurement caused by individual sheet attribute variances. Other ways for counting sheets have involved the use of devices, such as touch probes or other sensors, placed across the height of the pack. Such devices are relatively slow, alignment sensitive, and in the case of touch probes, require contacting the sheet edges which can introduce defects to the media.

Other conventional approaches are based on 2-dimensional image processing of a pack of media. These devices employ an imaging CCD array and subsequent processing of the 2-dimensional image. However, such devices lack spatial resolution, acquisition readout time, and are slow in that they require processing time for counting a large number of sheets, especially thin media. This is due in part to their use of 2-dimensional sensors of size n x n pixels which are limited in practice to pixel array formats of 512x512 or 1024x1024 pixels. Because of the 2-dimensional processing, these array formats have intrinsic acquisition, readout, and processing times in proportion to n^2, i.e., the total number of pixels in the 2-dimensional array. Furthermore, 2-dimensional image processing requires special counting methodology such as a data processing step of spatial averaging along the sheet edges or sampling multiple regions across the edge of the pack in order to avoid counting inaccuracies due to the wide range of edge cut quality of sheet media, and conditions in the pack such as recessed sheets and the presence of stiffener boards.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide an improved sheet counting apparatus for rapid accurate counting of various types of thin sheet media, especially when in a pack.

It is also an object of this invention to provide an improved apparatus for counting sheets of thin media by performing only one-dimensional image signal processing, whereby spatial resolution is increased, and processing time is reduced as compared to two-dimensional processing techniques. A one-dimensional signal corresponding to the sheets is provided to the one-dimensional signal processing preferably from a linear CCD array camera, which further reduces processing time while optimizing sheet resolution in the signal.

It is another object of this invention to provide an improved apparatus for counting sheets of thin media which automatically adapts to sheets having various edge conditions, and of media types having different coatings, substrates or sheet thickness, with or without stiffener boards either bounding or between the sheets, thereby reducing inaccuracy in the count.

A still further object of this invention is to provided an improve apparatus for counting sheets of thin media which can operate in both a stand-alone mode, or be integrated into a high speed in-process sheet pack counting operation.

The invention is not limited to apparatuses which

obtain each and every object and avoid each and every drawback mentioned above.

Briefly described, an apparatus in accordance with the invention for counting thin sheets of media includes a light source for illuminating the edge of a plurality of sheets. This plurality of sheets may represent a pack of sheets, or the rotational convolutions of a roll of media. A sensor array receives light reflected from the edge, and generates a signal representative of the reflected light corresponding to the sheets. The signal is then processed along one dimension of the edge to count the sheets in the plurality of sheets.

Signal processing is preferably carried out by determining a dominant frequency harmonic of the signal which corresponds to the sheets, and then isolating the dominant frequency harmonic in the signal. The resulting signal is further processed by locating the positions of the sheets in the signal.

The signal from the sensor array is also processed to provide the positions of any stiffener boards, which enables counting of the number of the stiffener boards. Stiffener board positions can also be used for locating the positions of sheets in the signal.

The foregoing and other objects and advantages of the invention will become more apparent when taken in conjunction with the following description and drawings wherein like characters indicate like parts and which drawings form a part of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a block diagram of the counting apparatus in accordance with the invention;
Figure 2 is a perspective view showing the use of the invention for in-line sheet pack counting;
Figure 3a-d are examples of signal waveforms illustrating exemplary sheet pack conditions;
Figure 4 is a flow chart showing the operation of the apparatus of Figure 1;
Figures 5a-d are exemplary signal waveforms illustrating the major signal processing steps for locating sheets of Figure 4;
Figures 6a-e are exemplary signal waveforms illustrating the major signal processing steps of Figure 4 for locating stiffener boards in a sheet pack; and
Figure 7 is an illustration of a roll of thin media having rotational convolutions which may be counted by this invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring first to Figure 1, there is shown a block diagram of the apparatus for counting sheets. This apparatus may either be configured in a stand-alone unit, as illustrated in Figure 1, or integrated into a sheet pack production operation. When the apparatus is a stand-alone unit, a pack 10, containing a plurality of sheets 8 of the same type of media, is placed upon a platen 12 which supports the pack (which may alternatively be an inclined bin), such that an edge 5 of the pack is located in the desired position in space by being indexed against a backreference plate 13 relative to the object imaging plane for imaging by the linear CCD array camera 20. This apparatus may be integrated, as a module of a machine producing the packs of media, wherein the pack is transferred using an automated mechanism from the machine (not shown in Figure 1) to the platen 12, and then returned to the machine for other processes than sheet counting, or redirected to a product reject bin or rework station.

Alternately, the apparatus may be used for in-process pack handling operations, as shown in Figure 2. The packs then can be oriented on a conveyer line 200 such that their edges 5 are positioned to be strobed by a LED array 24, and imaged by the linear CCD array camera 20. Although Figure 2 illustrates conveyer line 200, other automatic means for transferring and positioning the pack 10 may be used such as inclined bins for receiving packs 10. A cabinet 220 contains a computer 30 and other electronics of Figure 1, and supports the camera 20 and LED array 24. If during operation the pack 10 of media is determined to be of the correct count, the apparatus of Figure 2 will indicate that result via an annunciation by a tone or other indicator produced by a means in cabinet 220, or by sending the result to a higher level control computer (not shown) responsible for product disposition. The components of the counting apparatus are the same in Figure 2 as in Figure 1, except that pack positioning components 11, 12, 13, 15, 16 are absent, and a part sensor 210 senses and signals to the computer 30 when a pack is present. The foregoing and other components of the apparatus will hereinafter be described with reference to Figure 1.

The sheets 8 in pack 10 shown in Figure 1, may be of any type of thin sheet media, such as photographic film, paper, or plastics. The pack may contain stiffener boards 9, which are substantially thicker than the sheets 8 to increase pack 10 rigidity. Figure 1 show two stiffener boards 9 bounding the top and bottom of the pack 10. However, stiffener boards 9 may also be situated among the sheets at intervals to separate smaller sheet lots.

The counting apparatus includes and is controlled by a computer 30 shown in Figure 1 which may be a commercially available personal computer, workstation, minicomputer, or mainframe. Through a parallel I/O board 32 the computer 30 is interfaced to a pack-in-place photo-sensor 15 and piston/clamping sensor assembly 16 for controlling and monitoring the positioning of the pack against plate 13. Also through the parallel I/O board 32, the computer controls the illumination of the edge 5 via signals to a diode pulser circuit 26, and controls the imaging by the linear CCD array camera 20. A serial I/O board 38 in the computer 30 provides an interface for data output by the apparatus, such as sheet and stiffener board counts, to a touch screen panel display 40. The touch screen panel display 40 also serves

as a data input device to the computer by an operator. A central processing unit (CPU) 31 in the computer 30, coupled with a digital signal processor accelerator (DSP) 34, is used for performing signal processing and counting. Both the CPU 31 and DSP 34 have adequate memory for storing data representing signal waveforms during such processing, or may utilize RAM of a memory 33 for such storage. A video buffer/digitizer 36 digitizes and then stores a frame of the signal received from camera 20. The video buffer 36 is addressable by both the CPU 31 and DSP 34 during signal processing.

As described earlier, Figure 1 represents one means of positioning a pack 10 in an object image plane of the linear CCD array camera 20. A platen 12 supports the pack 10 of sheets 8 at a desired height relative to the imaging subsystem, i.e., the LED array 24 with lens 25, and linear CCD array camera 20 with associated imaging optics 21. The pack 10 may be introduced on the platen 12 using an automatic conveyance means (not shown in Figure 1) such as a transfer arm or shuttle mechanism, or may manually be placed on the platen 12 by the operator. The plate 13 has a recessed cutout for imaging or a series of pins aligned linearly to serve as a backfence defining an indexing surface for the pack at the object image plane for linear CCD array camera 20. It is important that the pack 10 presents a reasonably square edge of sheets 8 and stiffener boards 9 against plate 13 for accurate counting, and that the sheets 8 lying on platen 12 are in a substantially parallel relationship to each other at the pack edge 5. With the pack properly situated on the platen 12, a pack-in-place photo-sensor 15 generates a signal to the computer 30 to indicate that the pack 10 is located at the proper object image plane. The signal from this sensor 15 is sent to the CPU 30 via the parallel I/O board 32 to indicate whether the pack 10 is in place.

Compression of the pack 10 near the edge 5 may optionally be provided by a pressure plate 11 and the piston/clamping sensor assembly 16. Such compression is useful for sheet media which has a tendency to curl, i.e. or not lie flat. For example, a pneumatic or hydraulic piston in assembly 16 generates a controlled force on pressure plate 11 to slightly compress the pack of sheets. Through parallel I/O board 32, the CPU 31 controls the piston in assembly 16, and monitors that the piston is in proper position via the clamping sensor in assembly 16.

Once the computer 30 determines that the pack 10 is in position, the computer 30 sends a signal to a diode pulser circuit 26 which then operates the LED array 24 to flash (strobe) in synchronization with a video synchronization signal, from the computer 30 via the video buffer/digitizer 36, which drives the pixel line scan timing of the linear CCD array camera 20. The preferred means of illuminating a local region of the side of a pack is to direct the light from the strobed LED array 24 at the pack 10 at an oblique angle to the plane formed by the pack edge 5 against the indexing surface of the plate 13. Preferably, the LED array 24 has narrow band emittance in the near-infrared spectral region to make the illumination harmless to photo-sensitive media without inducing latent fogging exposure due to the LED array illumination. Further, the LED array 24 light may be directed onto the pack edge 5 via the cylindrical optics 25, such as a rod lens, positioned between the LED array 24 and the pack 10 to generate higher illumination levels upon the edge 5.

The strobed illumination is reflected from the pack edge 5 at a modulated intensity. The linear CCD array camera 20 is positioned to image the height of the pack 10. Camera 20 receives the reflected modulated light from the edge 5. The received light is modulated because it corresponds to the light reflecting alternately from sheets 8 and finite space between sheets 8 of the pack edge 5 surface, as well as any stiffener boards 9 which may border or are in the pack 10. This received light is stored as a proportional electronic charge in the CCD sensor elements of the linear CCD array camera 20, and is translated by the camera 20 into a signal which is sent to video buffer/digitizer 36. This signal represents a high resolution one-dimensional line scan of the reflected light and is used to produce a line of pixels in video buffer/digitizer 36, preferably, this line has 6000 pixels to accommodate packs with high sheet counts, such as 500 sheets. This type of imaging is preferred because it only has to acquire and process the pixels associated only with the linear CCD array camera 20 thereby providing acquisition rates as high as 60Mhz. This significantly improves the spatial resolution along the axis of interest which lies across the height of the pack. For thin sheet media such as film or paper with light sensitive emulsion coatings, camera 20 may be a wide aperture linear CCD array camera to minimize the light exposure of the product on sheet photo-sensitive surfaces.

The maximum height of the pack 10 that the apparatus can properly operate upon may be adjusted by directing light from the LED array 24 to strobe along the height of pack, and providing the linear CCD array camera 20 with a sufficient number of pixel sites in combination with the associated optic 21 to obtain a proper field of view for imaging the height of the pack. This increases the linear CCD array camera's field of view. For a pack extending beyond the original field of view of the camera 20, one may use a series of linear CCD array cameras which are aligned to make their respective object field of views contiguous, thereby, expanding the field of coverage, while maintaining high resolution across the height of the pack. In this manner, the length of the signal waveform may be increased to the height of the pack. Digitizing in video buffer/digitizer 36 may be modified to handle the increased signal length by operating in a multiplexed mode, or by using multiple digitizers.

The one-dimensional signal corresponding with the acquired scan from the linear CCD array camera 20 is

transmitted in analog form to the video buffer/digitizer 36 in the computer 30. The signal is digitized in video buffer/digitizer 36 by converting the analog signal into a gray scale pixel data signal. Once the signal is digitized, it is temporarily stored in a buffer in video buffer/digitizer 36 for subsequent signal processing by the DSP 34 and CPU 31 in accordance with an operating program stored in the memory 33 (RAM or ROM). This stored signal represents a one-dimensional line of pixels having gray scale values corresponding to the reflectivity variations in the light received and generated by the linear CCD array camera 20. In the preferred embodiment, the gray scale has 8 bits of resolution providing a range value from 0 to 255, where black is 0, and white is 255. Although not preferred, the linear CCD array camera 20 may alternatively be a digital camera which outputs a line of pixel data signal to the video buffer, thereby eliminating the above described digitizer.

Figures 3a-d show examples of signal waveforms from an imaged pack 10 which may be stored in the video buffer/digitizer 36. (The signal waveforms in Figures 3a-d, 5a-d, and 6a-e are shown as analog waveforms, but are processed as digital data, where the vertical axis represent the level of reflectivity, and the horizontal axis the position of the pixels in the signal.) Figure 3a represents a normal pack waveform, starting from a stiffener board 9, shown by wider and more reflective region, and a series of peaks representing the sheets 8 in the pack 10. The stiffener boards 9 in these examples are closer to white in color, denoting high reflectivity levels, however, the apparatus is adaptive to stiffener boards of other levels of reflectivity since subsequent processing is performed responsive to the stiffener board signal width rather than the level of stiffener board reflectivity. There are several conditions of the pack edge 5 which may appear in the signal waveform, as shown in Figures 3a-d. This apparatus accounts for these conditions during signal processing. Figure 3a shows a small peak 50 representing a contaminant on the edge 5 of the pack 10, such as may be caused by dust or grit. Figure 3b shows the effect 51 of a recessed sheet, which can result from a sheet which was not sufficiently indexed against plate 13, and hence had an edge positioned behind the other sheets 8. This causes insufficient reflected light from the recessed sheet to the linear CCD array camera 20. Figure 3c represents the effect of multiple coatings on the surface of the sheets 8 which may generate multiple pairs of peaks 52 of reflected light. Next, Figure 3d represents the case where a stiffener board's higher reflectivity levels shadows or masks sheets 53 nearest to the stiffener board. This can result from blooming effects on the CCD sensor elements in the linear CCD array camera 20 which can encompass the reflected light of sheets neighboring the stiffener board 9. Those skilled in the art should be able to envision a variety of other conditions, such as degraded edges due to the slit and cut of the sheets, that can impact the signal representing the sheets. This apparatus's signal processing, as will be discussed, can provide accurate counting despite the above conditions in the signal.

In reference to Figure 4, operation of the apparatus begins by the computer checking the placement of the pack 10. This is performed by the CPU 31 checking if the pack-in-place sensor 15 has sent a signal through the parallel I/O board 32 indicating that the pack 10 is in position. If the pack 10 is not in proper position, the CPU 31 indicates this to an operator by an output to the display 40, or by activation of sound generating circuitry in the computer 30. The pack 10 may then be repositioned by the operator. In an automated apparatus, repositioning of the pack 10 may be performed by a mechanical arm. Once the pack 10 is in position, the CPU 31 actuates the piston in assembly 16 into a clamping position upon the pack 10. The piston's position is monitored by the CPU 31 via the clamping sensor in the assembly 16. Compression of the pack need not be performed if edge curl of the sheet media is minimal.

When the clamping sensor is low (i.e., piston is in a proper clamped position), CPU 31 sets a specification count flag equal to one if a nominal sheet count specification has been provided by the operator via input on touch screen panel display 40. The nominal sheet count specification is the number of sheets expected to be in the pack, which can later be compared to the measured count after processing has been completed.

Next, the apparatus acquires an image of the pack edge 5 with linear CCD array camera 20 with adaptive reflected light level control, as described below. The computer controls the amount of reflective light received by camera 20 by adjusting the time the CCD elements in camera 20 integrate the received reflected light, also referred to as CCD integration time, which in turn effects the amplitude of the signal waveform produced by the camera 20. The integration time for the camera 20 is controlled via a signal to the camera 20 sent by CPU 31 through the parallel I/O board 32 (see Figure 1). A table in the memory of CPU 31 may be used to determine an initial setting for the CCD integration time. This table stores integration time data for various sheet types, which may be selected in response to the sheet type inputted by the operator through the touch screen panel display 40. Where no sheet type is specified, a default integration time may be accessed by the CPU 31 from its memory to provide an initial integration time setting. The CPU 31 sets the initial integration time to the camera 20 for subsequent imaging. The CPU 31 operates the diode pulser circuit 26 to synchronize the LED array 24 illumination of the pack edge 5 with the camera 20 receiving of the reflected light from the edge 5. The camera 20 operates by receiving a first scan of the reflected light for clearing out the video buffer 36, and then a second scan which is digitized and stored in video buffer/digitizer 36.

The CPU 31 then addresses a region of interest (ROI) from the stored signal representing several sheets. The ROI may be obtained by sampling one or

more windows of pixels in the signal, and then calculating a mean intensity of reflectivity within the ROI. It is preferred that multiple sample windows be used when stiffener boards exist within a pack 10 in order to generate a mean intensity more representative of the sheets 8. If the calculated mean intensity is outside a nominal range for intensity, the integration time for the camera 20 will be calculated by using the difference between the calculated mean intensity and the nominal range. This calculation is in accordance with the approximately linear response between this difference and a corresponding change in integration time. The nominal range is defined as the desired intensity (i.e. amplitude of reflectivity) of the signal, which may be a scale set point near the middle of the signal's intensity range. The camera 20 is set by CPU 31 to the calculated integration time, and the LED array 24 is strobed once again. The camera 20 then performs two scans, as described above, and the second scan is stored in the video buffer/digitizer 36. The integration time for the camera 20 will continue to be adjusted in this manner until a signal having a mean intensity within the nominal range is obtained. Although the above method of adaptive light level control is preferred, alternatively, the intensity of the reflected illumination of the edge 5 may be controlled by the CPU 31 by reducing the level of the LED array 24 illumination through a signal to the diode pulser circuit 26. In this manner, the apparatus is responsive to the varying reflectivity of different types of sheet media.

Once the signal is digitized and stored in the video buffer/digitizer 36, the CPU 31 and the DSP 34 execute signal processing on the stored signal waveform as follows: Reference is made to Figures 5a-d to show the signals during processing for identifying sheets 8 in the pack 10, and to Figure 6a-e to show the signals during processing for identifying stiffener boards 9 in the pack 10. A Gaussian smoothing filter is first applied to the signal to remove any high frequency peaks in the signal, such as caused by noise, which may later effect signal processing. This filtering does not effect sheet or stiffener board information contained in the signal waveform. The Gaussian smoothing filter need not be performed on a signal having low levels of high frequency noise.

After the filter operation, the pixel regions in the signal beyond the sheet pack are zero padded. Zero padding is useful prior to digital frequency processing to avoid spurious frequency harmonics, as those knowledgeable in the art can appreciate. For example, if digital frequency processing were to be performed on a signal composed of 2,048 pixels, but only 2,000 pixels resulted from imaging of the pack, the signal is padded until a power of 2 is reached, which in this case is 2,048.

Before the above zero padding operation, steps may be added to limit frequency processing to the portion of the signal between a pair of stiffener boards 9 in the pack 10. For example where two stiffener boards bound either side of the pack, frequency processing may be performed on the pixels in the signal between these stiffener boards. This narrowing of the region of interest can improve frequency analysis operations on sheet signal content by removing signals associated with stiffener boards. This narrowing may be achieved by locating the stiffener boards in the signal, and then addressing pixels only between stiffener boards. Stiffener boards may be identified by the CPU 31 because they have wider base line pixel regions in the signal. Once the region of interest is narrowed to sheet information, then the above described zero padding is performed prior to digital frequency processing in the DSP 34.

The DSP 34 performs a one-dimensional Fast Fourier Digital Transform (FFT) to generate a representation of the signal waveform in the frequency domain. The DC harmonics are then removed from the signal waveform by the CPU 31. The CPU 31 then determines a dominant frequency harmonic from the signal by determining the highest frequency, i.e., the part of the signal having the greatest number of repeating waveform cycles. This dominant frequency harmonic contains the part of the signal representing the sheets 8 in the pack 10. A bandpass filter is then applied by the CPU 31 about the dominant frequency harmonic to isolate the part of the signal representing the sheets by removing any signal baseline noise or stiffener board signals. Thereafter, an inverse FFT operation is performed by the DSP 34, which produces a signal representing the sheets in the spatial domain. An example of the processed signal waveform is shown in Figure 5b.

All possible peaks associated with sheets in the signal are then determined by the CPU 31 by adjacent pixel comparison, in which paired pixel slopes are compared with an intensity profile of a possible peak associated with a sheet location the pack 10. The intensity profile, or slope discriminant criteria, is empirically determined to properly identify peaks and hence sheet locations. This operation discounts any individual peaks in the signal that do not meet the derived profile criteria in terms of overall height, slopes of edges, or localized intensity maxima criteria. After identifying all possible peaks, the CPU 31 calculates in the signal a weighted centroid within each sheet peak. This centroid represents the possible location of a sheet based on the width and height of a peak. Figure 5c shows these weighted centroids for the signal of Figure 5b. At this point, not all the sheets 8 in the pack 10 need be represented by centroids, but a sufficient number of centroids are necessary so as not to adversely effect subsequent processing using the estimate of the mean sheet center-line to center-line spacing, as described below.

The CPU 31 then uses the previously determined dominant frequency harmonic to calculate an estimate of the mean sheet center-line to center-line spacing, also referred to as an average pitch distance. Using this average pitch distance, the CPU 31 scans the signal to verify that all the weighted centroids are valid relative to

the average pitch between sheets. This is performed by interrogating two or more adjacent centroids in the signal to determine if their proximity to each other is valid given the finite amount of space between adjacent sheets specified by an integer multiple of the average pitch +/- X standard deviations from that average, preferably X equals six. The standard deviation may be determined when the average pitch calculation is made. If a centroid is found which cannot fit among adjacent centroids, then that centroid is discounted and eliminated in subsequent processing. In this manner each centroid is interrogated in the signal to determine whether it qualifies as a possible sheet location.

Using centroids which have not been discounted, the CPU 31 scans the signal to interpolate in the signal centroid locations which may exist between adjacent centroids according to the average pitch between sheets. In other words, if an interval between centroids is large enough to fit one or more centroids within the average pitch distance +/-a standard deviation from that average, then such centroids are added within that interval. This not only accounts for false sheet peaks, but for any missing sheets in the signal, which may be due to recessed sheets in the pack.

In parallel with the above operation, the original signal in video buffer/digitizer 36 is also processed by the DSP 34 to determine the location and count of any stiffener boards 9 in the pack 10. Figure 6a shows the original signal waveform. First, the CPU 31 calculates a nominal sheet width based on the earlier determined dominant frequency harmonic. This nominal sheet width is an estimate of the base width extent of signal peaks associated with the sheets 8. Using morphological processing techniques, the DSP 34 applies a morphological opening structure element (not shown) to the original signal waveform having a pixel width greater than the nominal sheet width, but less than the expected width of a stiffener board 9 in the pack 10. The resulting waveform is shown in

Figure 6b. Morphological processing operates on the signal by sorting signal peak base-widths by the width of a structuring element, and transforms each peak which is less wide than the structuring element to a baseline value for the peak. The signal waveform after this morphological operation is saved as Sheets Opening in DSP 34 memory or the memory 33. A second morphological opening structure is then applied by the DSP 34 to the signal having a width much greater than the extent of any stiffener board 9. The resulting signal after applying the second morphological opening structure is shown in Figure 6c. The signal after the second morphological process is subtracted from the stored Sheets Opening signal, and the resulting residue signal is shown in Figure 6d. In this manner the peaks associated with each stiffener board 9 are isolated from the signal. Next, a threshold function is applied to the opening residual signal to locate the edges of the stiffener boards 9, as shown in Figure 6e. This threshold function is adaptive in that the threshold level above which a stiffener board edge is located is set to a percentage of the peak's maximum intensity. This percentage is empirically derived to assure that the threshold function locates the stiffener board edges. The stiffener board count is then calculated by the CPU 31 by dividing the number of located edges in the signal by two.

Signal processing for identifying sheets in the signal waveform continues by performing a second interpolation of weighted centroids using the above located stiffener board edges when stiffener boards 9 were either located by the above processing, or were known to be in the pack via input from display 40. This second interpolation is performed by first determining if the spacing interval between the edge of the stiffener board 9 to the nearest sheet peak centroid is large enough to contain one or more sheets based on the earlier calculated average sheet pitch. If so, then additional centroids are interpolated and located in this spacing interval. The second interpolation occurs along the inner edge of any stiffener boards bounding the pack, and on the outside of both edges for any stiffener boards 9 within the pack 10. This accounts for any sheets which were masked due to possible CCD element blooming effects of the stiffener boards 9 during imaging by camera 20, or missing sheets due to recessed sheets adjacent to the stiffener boards 9.

The CPU 31 then calculates a total sheet count by adding all weighted centroids not discounted, and interpolated centroids in the signal waveform. Thereafter, the CPU 31 checks whether the specification count flag set previously equals 1, if so, the count is compared to the expected sheet count value for the pack stored in CPU 31 memory. If there is a difference between the count and the expected sheet count, then sheets are accordingly added or removed from the pack 10 to provide a pack count equalling the expected sheet count. This may be performed by an operator, or through an action to correct the count of the pack 10 by a mechanism capable of adding or removing sheets in the pack 10. This mechanism could consist of means such as a robotic transfer arm or dedicated actuator to add or remove media sheets. After assuring that the number of sheets in the pack 10 equal the expected count value, or if the flag did not equal 1, the count of the number of sheets 8, and of the stiffener boards 9, if any, are displayed on display 40. A query is then made as to whether additional scans of the pack 10 are requested by the operator and if so, the pack is again counted; otherwise, the pack of sheets is removed from platen 12 for product disposition.

Referring now to Figure 7, this invention in addition to providing sheet pack counting, may also be used to count the number of convolutions of a roll of thin media. Figure 7 shows a roll 70 (also referred to as a wound web) in a side perspective having cylindrical core 72 and a number of rotational thin media convolutions 74. The apparatus operates by strobe illuminating with LED ar-

ray 24 the side of the roll 70 along the length of a radial line 76. The linear CCD array camera 20 receives the light reflected from the roll along this radial line 76 to provide a signal waveform. The roll 70 has been positioned to provide the proper object image plane to the linear CCD array camera 20 along the length of radial line 76. Signal processing thereafter is performed in the manner described earlier, except that stiffener boards 9 are substituted by the core 72, and the count represents the number of roll convolutions rather than the number of sheets 8 in the pack 10.

Note that the media convolutions near the radial line 76 provide a surface edge in which each media convolution has an edge portion substantially parallel to each other, whereby, from a signal processing stand point, the roll 70 along radial line 76 is similar to a sheet pack 10.

Although in the preferred embodiment the linear CCD array camera 20 is used, other means are available to acquire a one-dimensional signal than described above. One such means is to use a static two-dimensional CCD array to provide a two-dimensional signal, and additional signal processing to translate the signal into a one-dimensional signal along the height of the pack 10. To achieve this, the two-dimensional CCD array includes rows and columns which are positioned to the pack 10 such that the rows of the array align approximately with the sheets 8 in the pack 10. Additional signal processing then averages the values within each row or samples one column to produce a one-dimensional signal. Also a one-dimensional signal may be acquired using another type of two-dimensional CCD array, a time delay integration CCD array (TDI). The TDI is aligned like the above static two-dimensional CCD array, but scans across the length of edge 5 to integrate or sum signals across each row of the TDI. The TDI then outputs a one-dimensional signal representing the integrated rows.

The above two described alternative means of acquiring a one-dimensional signal cannot readily address counting convolutions of a roll 70 of thin media since the horizontal rows of the two-dimensional CCD array cannot adjust to the media curvature of convolutions 74. However, a wedge ring CCD array may be used to provide a two-dimensional signal which is aligned such that rows of the array match the curvature of the media convolutions 74. Once a one-dimensional signal is acquired using either a one or two-dimensional CCD array, the signal is then digitized and stored in the video buffer/ digitizer 36 before initiating the one-dimensional processing as described above in reference to Figures 3-6.

The above alternative ways of acquiring a one-dimensional signal are less desirable than the preferred linear CCD array camera 20 because a two-dimensional CCD array capable of the same level of resolution as the linear CCD array camera 20 is more expensive, generates longer processing times due to additional processing needed to obtain a one-dimensional signal, and has greater alignment sensitivity than the camera 20 since the rows of the two-dimensional CCD array need to line up approximately with the sheets (or in the case of the wedge ring CCD array the curvature of the media). One reason for the reduced alignment sensitivity of the linear CCD array camera 20 is because of the adaptive nature of the above described one-dimensional signal processing. In fact, so long as the camera 20 provides a signal waveform having sufficient resolution of the reflected light from edge 5 corresponding to the sheet 8 edges (or stiffener boards 9) in pack 10, or each convolution 74 edge in the case of roll convolution counting, the camera's one-dimensional imaging may depart at some slope from a dimension or vertical axis along the height of the pack 10, or the radial line 76 of the roll 70.

From the foregoing description it will be apparent that there has been provided a improved thin sheet media counting apparatus. Variations and modifications in the herein described apparatus in accordance with the invention, will undoubtedly suggest themselves to those skilled in the art. Accordingly, the foregoing description should be taken as illustrative and not in a limiting sense.

Claims

1. An apparatus for counting thin sheets of media comprising:

   a light source for illuminating an edge of a plurality of sheets forming a pack;
   a sensor array for receiving the light reflected from said edge of said plurality of sheets, and generating a signal representative of said reflected light corresponding to said sheets; and
   a processor for processing said signal along one dimension of said edge to count the sheets in said plurality of sheets.

2. An apparatus as recited in claim 1 further comprising:

   a digitizer for converting said signal from an analog signal to a digital signal;
   a buffer for storing said digital signal, said sensor array being a linear CCD array, and said processing means processes said digital signal stored in said buffer for locating the positions of a sufficient number of said sheets, interpolating the positions of any missing sheets relative to said located sheets, and counting said located sheets and said interpolated sheets.

3. An apparatus as recited in claim 2 wherein said plurality of sheets of said sheets includes at least one stiffener board, and said processor further processes said stored signal in said buffer locating the po-

sitions of said stiffener boards in said pack, and further interpolating the positions of any missing sheets relative to said located stiffener boards.

4. An apparatus as recited in claim 2 wherein:
said sensor array has means for controlling the intensity of said signal in response to said reflected light such that said signal has an average intensity within said response range for said processing means, and sensor array generates a one-dimensional signal responsive to variations in said reflected light representative of said edge.

5. An apparatus as recited in claim 3 wherein:
said processor for processing said signal generated by said sensor array includes:

means for locating the positions of said stiffener boards in said pack;
means for counting the number of said stiffener boards in said pack responsive to their positions;
means for locating the positions of a sufficient number of said sheets;
means for interpolating the positions of any missing sheets relative to said located sheets and said located stiffener boards; and
means for counting said located sheets and said interpolated sheets.

6. An apparatus as recited in claim 5 wherein:
said processor for processing said signal generated by said sensor array further includes:

means for determining a dominant frequency harmonic of said signal which corresponds to said sheets;
means for calculating the sheet width based on said dominant frequency harmonic;
means for isolating, responsive to said calculated sheet width, peaks in said signal having widths corresponding to said stiffener boards; and
means for locating the positions of said stiffener boards in said pack operative on the signal produced by said isolating means;
means for locating in said signal, responsive to said dominant frequency harmonic, the positions of a sufficient number of said sheets;
means for interpolating in said signal the positions of any missing sheets relative to said located sheets and said located stiffener boards; and
means for counting said located sheets and said interpolated sheets.

7. A method for counting the number of layers of media of a plurality of layers, said method comprising the steps of:

illuminating said plurality of layers with light incident on an edge of said plurality of sheets;
receiving the light reflected from said edge;
generating a signal representative of variations in said reflected light corresponding to said layers; and
processing said signal along one dimension of said edge to count the layers in said plurality of layers.

8. A method as recited in claim 7 wherein said processing step includes the steps of:

determining a dominant frequency harmonic of said signal, wherein said dominant frequency harmonic corresponds to said layers; and
isolating said dominant frequency harmonic in said signal.
locating the positions of a sufficient number of said layers;
interpolating the positions of any missing layers relative to said located layers; and
counting said located layers and said interpolated layers.

9. A method as recited in claim 8 wherein said plurality of layers comprises a plurality of sheets forming a pack and said pack includes at least one stiffener board, said method further comprising the steps of:

locating the positions of said stiffener boards in said pack; and
interpolating the positions of any missing layers relative to said located stiffener boards.

10. A method as recited in claim 8 wherein:
each of said plurality of layers comprises a convolution of spirally woundmedia forming a roll.

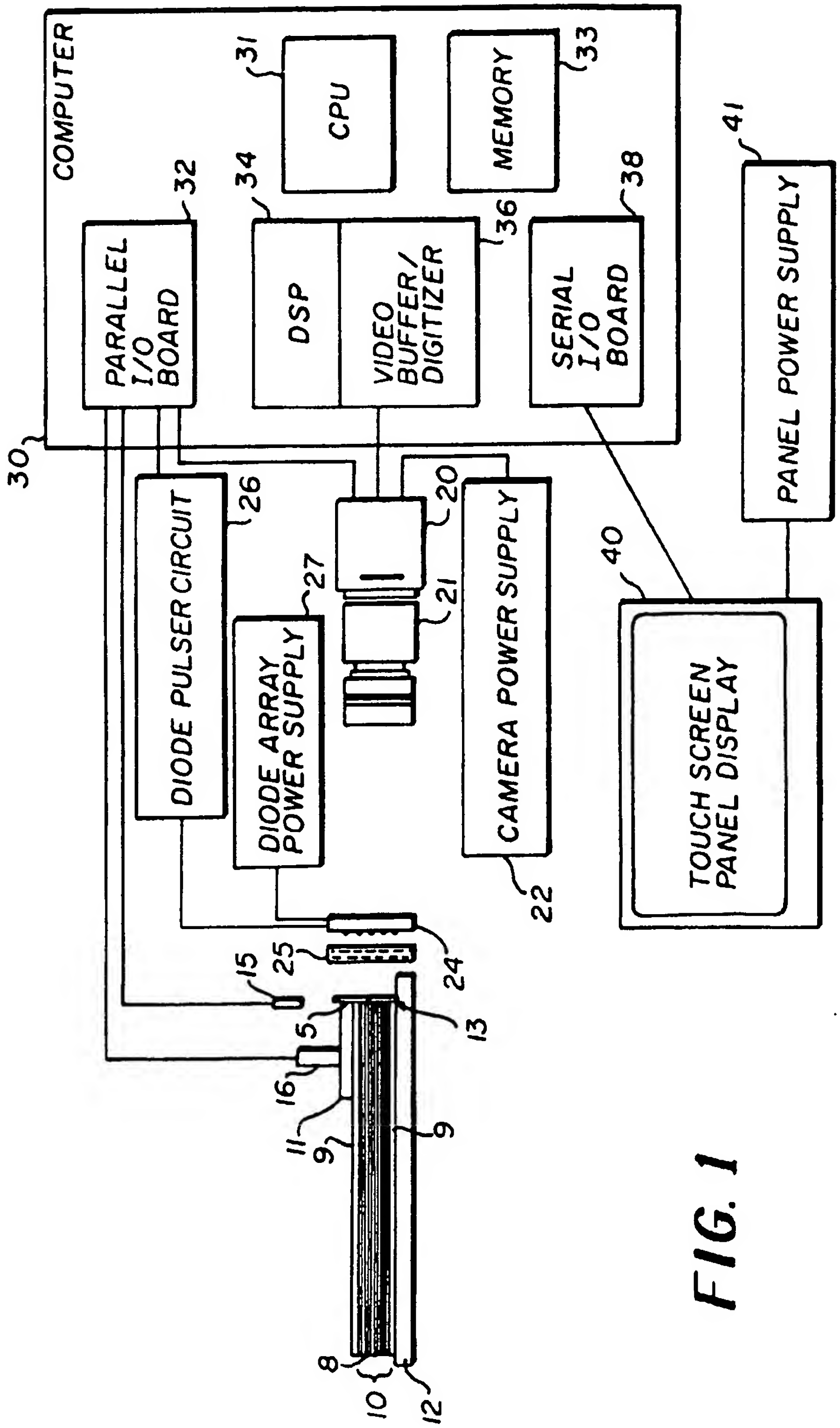

COMPUTER
30
CPU
31
MEMORY
33
PARALLEL I/O BOARD
32
DSP
34
VIDEO BUFFER/ DIGITIZER
36
SERIAL I/O BOARD
38
PANEL POWER SUPPLY
41
DIODE PULSER CIRCUIT
26
DIODE ARRAY POWER SUPPLY
27
20
21
CAMERA POWER SUPPLY
22
40
TOUCH SCREEN PANEL DISPLAY
24
25
15
5
13
16
11
9
9
8
10
12

FIG. 1

FIG. 2

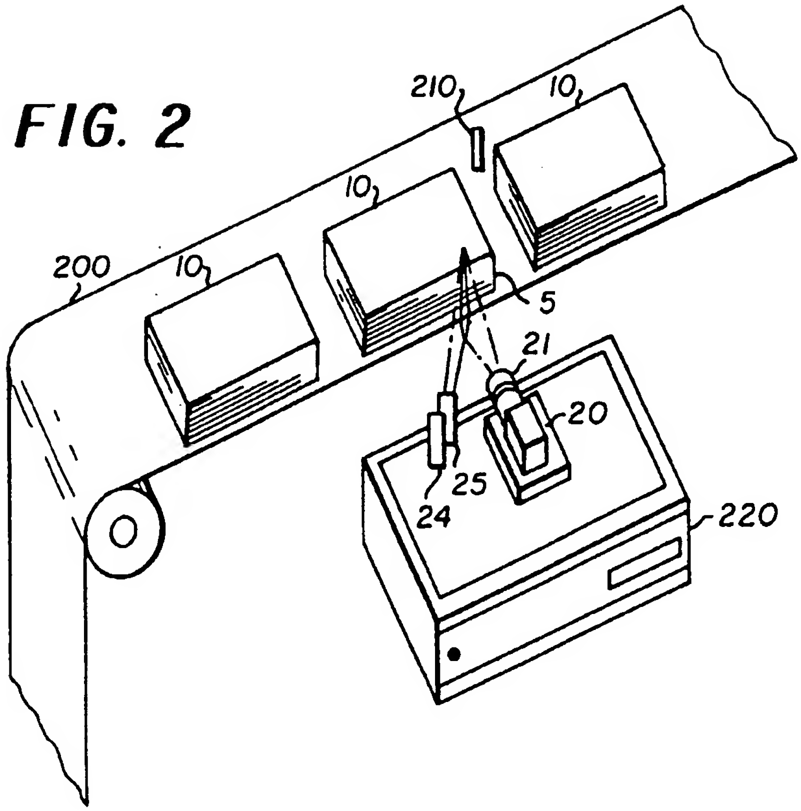
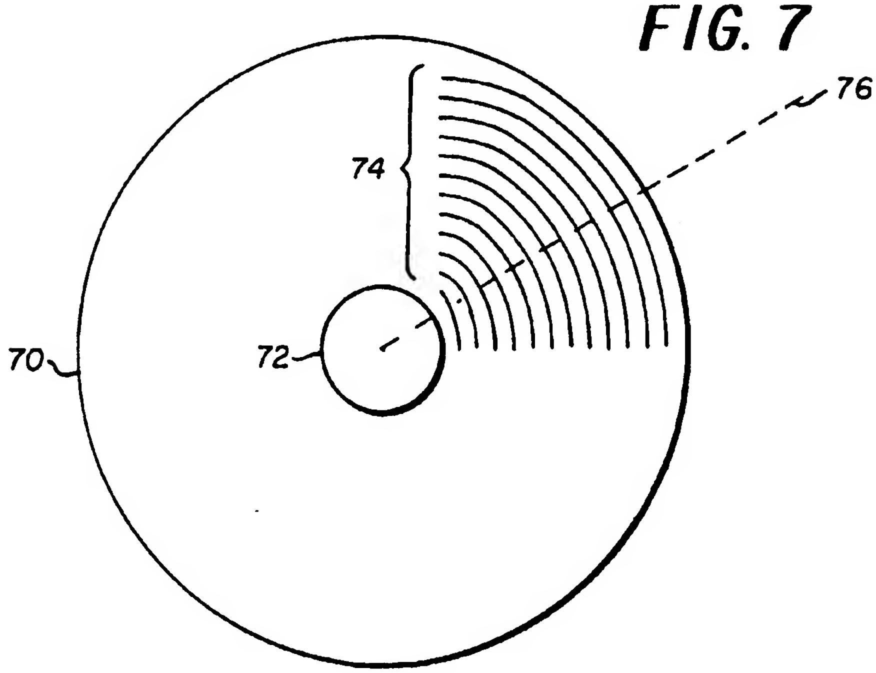


FIG. 7



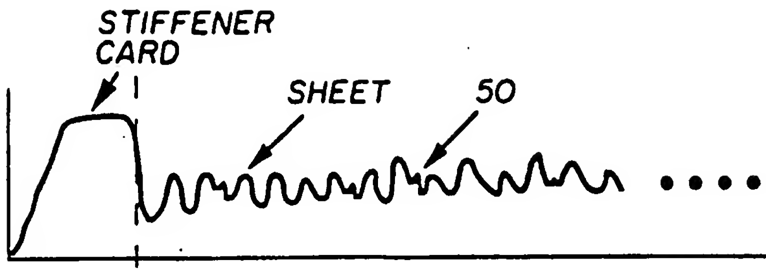


FIG. 3a

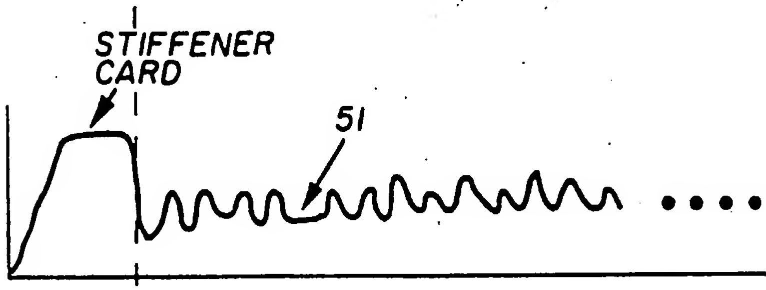


FIG. 3b

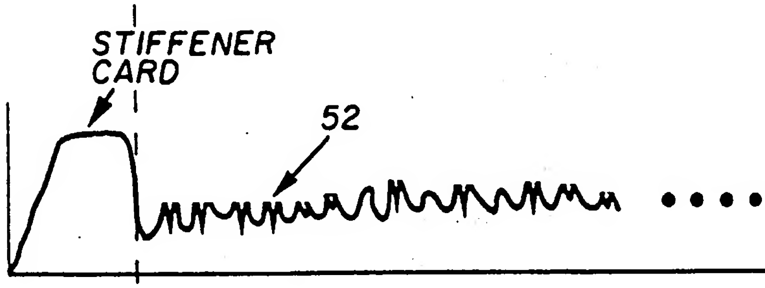


FIG. 3c

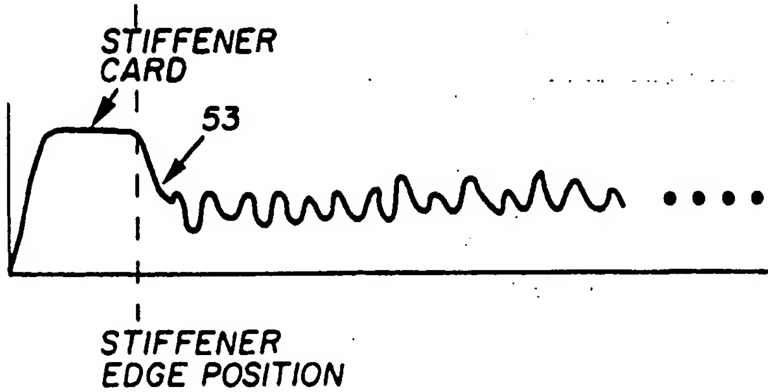


FIG. 3d

FIG.4

FIG.4a

FIG.4b

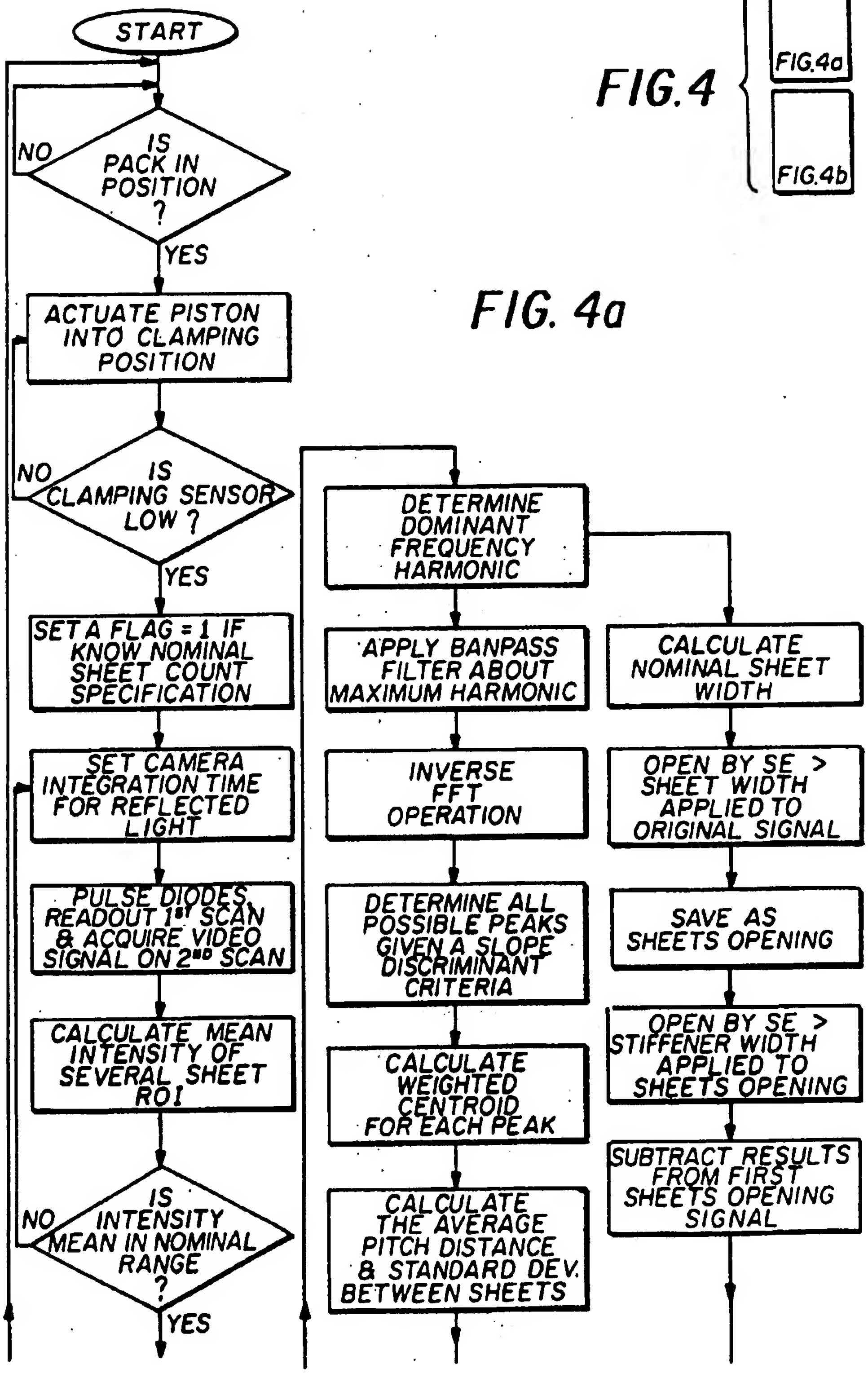


FIG. 4a

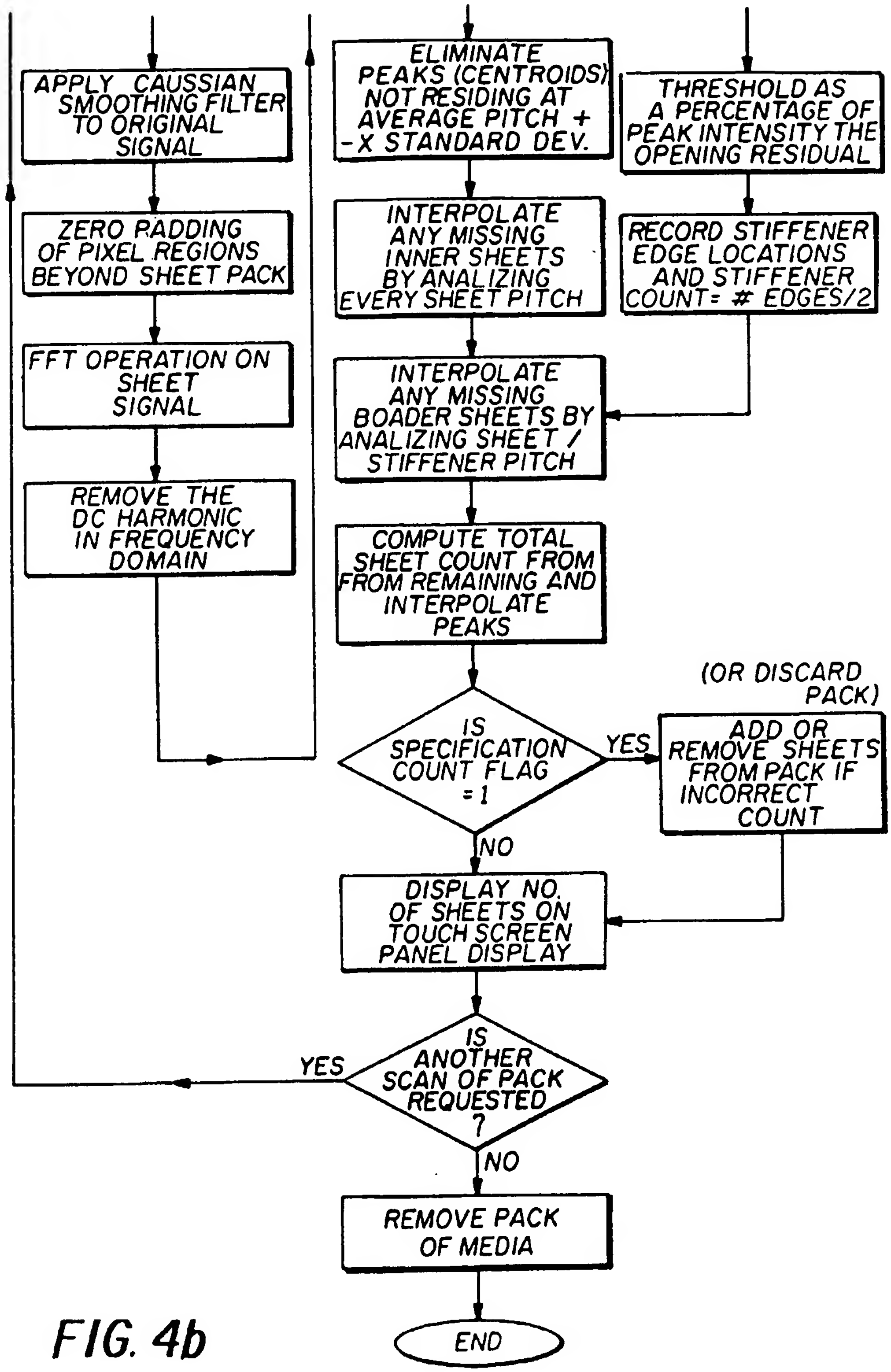

APPLY CAUSSIAN SMOOTHING FILTER TO ORIGINAL SIGNAL
ZERO PADDING OF PIXEL REGIONS BEYOND SHEET PACK
FFT OPERATION ON SHEET SIGNAL
REMOVE THE DC HARMONIC IN FREQUENCY DOMAIN
ELIMINATE PEAKS (CENTROIDS) NOT RESIDING AT AVERAGE PITCH + -X STANDARD DEV.
INTERPOLATE ANY MISSING INNER SHEETS BY ANALIZING EVERY SHEET PITCH
INTERPOLATE ANY MISSING BOADER SHEETS BY ANALIZING SHEET / STIFFENER PITCH
COMPUTE TOTAL SHEET COUNT FROM FROM REMAINING AND INTERPOLATE PEAKS
THRESHOLD AS A PERCENTAGE OF PEAK INTENSITY THE OPENING RESIDUAL
RECORD STIFFENER EDGE LOCATIONS AND STIFFENER COUNT= # EDGES/2
IS SPECIFICATION COUNT FLAG =1
YES
(OR DISCARD PACK)
ADD OR REMOVE SHEETS FROM PACK IF INCORRECT COUNT
NO
DISPLAY NO. OF SHEETS ON TOUCH SCREEN PANEL DISPLAY
IS ANOTHER SCAN OF PACK REQUESTED ?
YES
NO
REMOVE PACK OF MEDIA
END

FIG. 4b

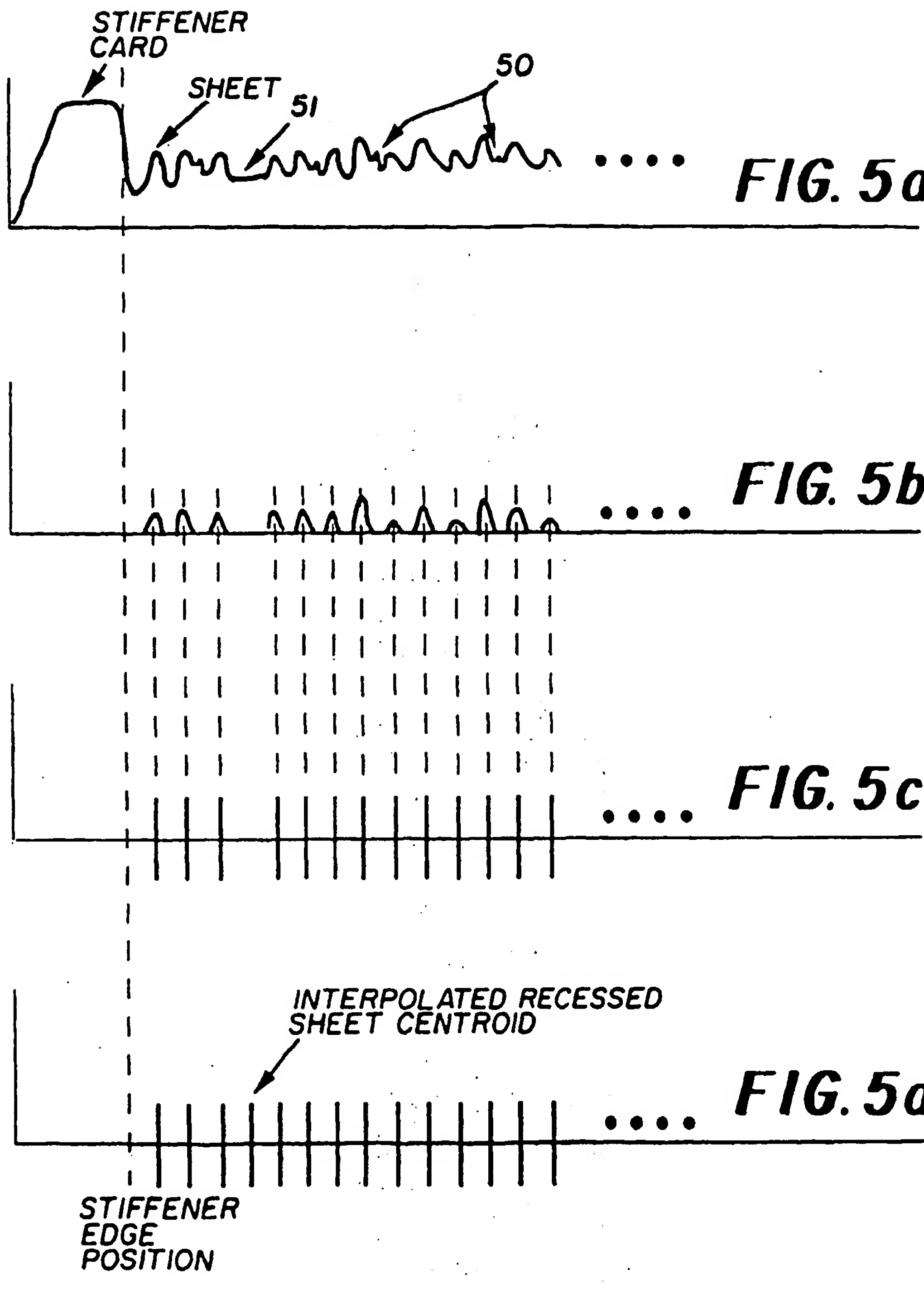


FIG. 5a

FIG. 5b

FIG. 5c

FIG. 5d

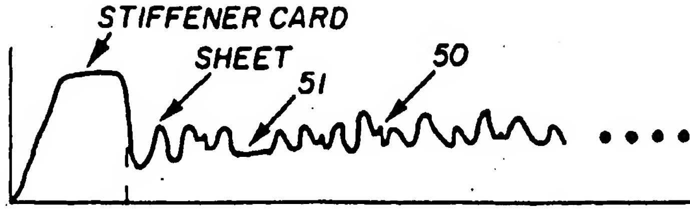


FIG.6a

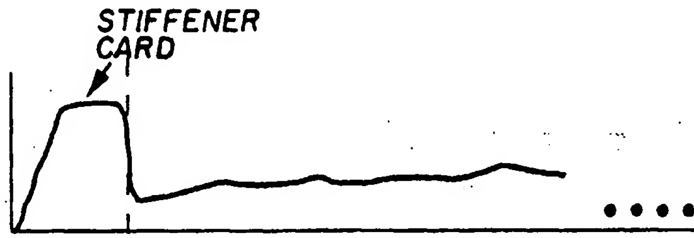


FIG.6b

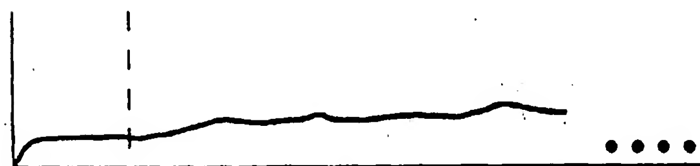


FIG.6c

FIG.6d

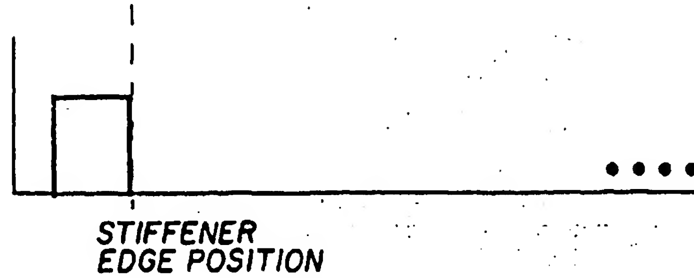


FIG.6e